Broadening volcanic eruption forecasting using transfer machine learning.

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On 9 Dec 2019, Whakaari (White Island) erupted suddenly, killing 21 people. It was the 5th eruption in ten years.
At present, a Volcano Alert Level (VAL) is determined through expert consensus. This could be complemented with real-time forecasting.

Whakaari was at VAL 2 before 2019 eruption.

[Potter et al., JAV, 2014]
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Goal: broaden forecasting ability to other seismometers
Goal: broaden forecasting ability to other seismometers and other volcanoes.
1. The **missing data** problem. Records at WIZ and WSRZ have gaps.

2. The **data comparison** problem. WIZ and WSRZ record the same(ish) signal, but at different amplitudes.

3. The **generalisation** problem. Ruapehu has fewer recorded eruptions – what can be transferred from the Whakaari forecaster?
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WSRZ not operating during 2012 eruption and had outages before Oct 2013 eruption.
Gap-filling: regression of concurrent pre-eruption features then stochastic interpolation.

- **Average**
- **Max**
- **# Peaks**
- **Gradient**
- **Fourier coefficients**
- **Total energy**
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A WSRZ forecast model trained using gap-filling performs about as well as the WIZ model trained on all the data.← WSRZ with gap-fill

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← WSRZ with gap-fill
Best score: 0.83

← original WIZ
Best score: 0.9
A WSRZ forecast model trained using gap-filling performs about as well as the WIZ model trained on all the data.

WSRZ with gap-fill →
Best score: 0.94

original WIZ →
Best score: 0.94
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It would be better if there were some universal standard that signals could be transformed back to.
The raw data are somewhat log-normally distributed.
The raw data are somewhat log-normally distributed, so we used a log unit-normal transformation.
The result is improved (if still imperfect) overlap between the signals.
Models trained on standardized signals perform about as well on the out-of-sample eruptions used for testing.
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original forecast

with standardized data...

...and regional EQs removed
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3. The **generalisation** problem. Ruapehu has fewer recorded eruptions – what can be transferred from the Whakaari forecaster?
Standardise and merge data records for different volcanoes. Naively train and test forecast models.

**Whakaari**
- 10 years of standardized RSAM data
- 7300 windows, 20 pre-eruption
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**Whakaari**
- 10 years of standardized RSAM data
- Five eruptions (2012, 2x'13, '16, '19)
- 7300 windows, 20 pre-eruption
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**Whakaari**
- 10 years of standardized RSAM data
- Five eruptions (2012, 2×'13, '16, '19)
- 7300 windows, 20 pre-eruption

**Ruapehu**
- 15 years of standardized RSAM data
- Two eruptions (2006, 2007)
- 11 000 windows, 8 pre-eruption
Standardise and merge data records for different volcanoes. Naively train and test forecast models.

**Whakaari**
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**Ruapehu**
- 15 years of standardized RSAM data
- Two eruptions (2006, 2007)
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Standardise and merge data records for different volcanoes. Naively train and test forecast models.

**Whakaari-Ruapehu**
- 25 years of standardized RSAM data
- Seven eruptions (2006, '07, '12, 2×'13, '16, '19)
- 19,000 windows, 28 pre-eruption
Standardise and merge data records for different volcanoes. Naively train and test forecast models.

**Whakaari-Ruapehu**
- 25 years of standardized RSAM data
- Seven eruptions (2006, '07, '12, 2×'13, '16, '19)
- 19,000 windows, 28 pre-eruption

**Diagram:**
- Train
- Test
- RSAM [μm s⁻¹]
- Ensemble mean
- Eruption forecast
- Alert threshold

**Graph:**
- Time period from 29 Sep to 05 Oct
- Eruption timeline with alert threshold and RSAM values.
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**Whakaari-Ruapehu-Tongariro**
- 40 years of standardized RSAM data
- Nine eruptions (2006, '07, 3×'12, 2×'13, '16, '19)
- 29 000 windows, 36 pre-eruption

*(coming soon)*
We are addressing the “not enough data” problem in forecasting, using:

- feature interpolation to fill in network gaps,
- data standardization,
- transfer-learning for multi-volcano models.

More details in: